Superior Energy Performance U.S. DEPARTMENT OF ENERGY

Superior Energy Performance® (SEP™)

Measurement & Verification Protocol

Revision Date: 08 March 2017

U.S. DEPARTMENT OF ENERGY

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1. Introduction

Superior Energy Performance® (SEP™) is a certification program that recognizes excellence in energy management. Certification to the SEP program requires certification to *ISO 50001 Energy management system - Requirements with guidance for use* and third-party verification of energy performance improvement. Specific requirements for SEP certification are defined in the ANSI/MSE 50021 *Superior Energy Performance - Additional Requirements for Energy Management Systems* standard and its normative references. This *SEP Measurement and Verification Protocol (SEP M&V Protocol)* is a normative reference for ANSI/MSE 50021.

ISO 50001 requires that the energy performance and energy performance improvement of a facility are monitored, measured, and analyzed at planned intervals. SEP uses facility-monitored energy performance, beginning in a baseline period and ending with a reporting period, in order to determine a verifiable improvement in energy performance. Facility wide energy performance improvement is reported using the program-specific SEP Energy Performance Indicator (SEnPI).

1.1 The Superior Energy Performance Measurement & Verification Protocol

The *SEP M&V Protocol* sets forth the verifiable methodology for determining and demonstrating achievement of the energy performance improvement level claimed by an organization for a defined facility. Deviations from the requirements within this document are allowable only with written SEP Administrator approval following the SEP Administrator's evaluation of the justification provided by the organization. Contact information for the SEP Administrator can be found on the SEP website. The primary audiences for this document include facility team members responsible for determining the SEnPI, SEP Performance Verifiers, and the verification body that certifies energy performance improvement.

Determination of energy performance improvement includes accounting for energy consumption, normalization for relevant variables through adjustment modeling, and calculation of energy performance improvement. The determination and demonstration of energy performance improvement is based upon the comparison of two facility-wide approaches to calculating energy performance improvement.

- **Top-Down.** Top-down energy performance improvement is based upon facility-wide energy consumption by accounting of all energy types that are delivered into or away from the facility boundaries. Top-down energy performance improvement is calculated as the ratio of baseline period to reporting period facility-wide consumption, with adjustments to make the two periods comparable. The top-down analysis is the initial basis for determining facility-wide energy performance improvement for the purposes of SEP conformance and certification.
- **Bottom-Up.** Bottom-up energy performance improvement is based upon facility-wide energy performance improvement calculated by aggregating energy saving from individual energy performance improvement actions. The bottom-up analysis serves as a required comparison to the top-down approach.

1.2 About this Version

The *SEP M&V Protocol* contains requirements necessary to demonstrate, through the SEnPI, the achieved energy performance improvement for the SEP program. The requirements are located in the body of this Protocol and in normative annexes.

The *SEP M&V Protocol* was initially developed and released in 2012. Based upon stakeholder feedback, the SEP program has been updated, requiring modification of the 2012 version of the *SEP M&V Protocol*. The structure and language of the *SEP M&V Protocol* was updated to reflect common elements between ISO 50001 and supporting standards such as ISO 50015 and ISO 17747.

2. Normative References

The following referenced documents are indispensable for the application of the *SEP M&V Protocol*. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

- ISO 50001 *Energy management system - Requirements with guidance for use*
- ANSI/MSE 50021 *Superior Energy Performance - Additional Requirements for Energy Management Systems*
- *Superior Energy Performance Certification Protocol*

3. Terminology and Reference Notation

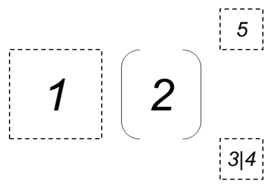
3.1 Terminology

For the purposes of this document, the following terms and definitions apply. These definitions can be found in ANSI/MSE 50021.

- achievement period
- baseline period
- boundaries
- delivered energy
- derived energy
- energy
- energy accounting
- energy consumption
- energy performance
- energy services
- energy use
- F-test
- facility
- feedstock
- non-routine adjustment
- normalization
- organization
- p-value
- primary energy
- relevant variable
- reporting period
- SEP energy performance indicator (SEnPI)
- static factor

3.2 Reference Notation

This section describes the notation used in this Protocol. The energy consumption and savings notation is designed to distinguish quantities in the format shown below. Annex A provides a table of all notation used in this Protocol.



1. **Base Notation:** Describes if the energy consumption or savings is for delivered or primary energy and provides the base for energy performance improvement notation.
2. **Energy Types:** Describes the type of energy that is quantified. The asterisk (*) notation is used as a placeholder for a generic or unknown energy type.
3. **Modeled Period:** Indicated in subscripts and defines the time period for which the model is built.
4. **Period/Conditions of Interest:** Indicates the time period or conditions of interest for which the model is being applied to.
5. **Adjustment Indicator:** Indicated in superscripts and describes if the quantity of energy is observed (actual) or adjusted.

1. Base Notation

ECP(*)	Primary energy consumption of an unspecified energy type
ECD(*)	Delivered energy consumption of an unspecified energy type
E(*)	Quantity of energy of an unspecified type
ESP(*)	Primary energy savings of an unspecified energy type
ESD(*)	Delivered energy savings of an unspecified energy type
EnPI	Energy Performance Indicator
SEnPI	Superior Energy Performance Indicator

2. Energy Types

Individual energy type notation replaces the asterisk (*) in parentheses from the base notation above. The following are recommended for clarity of communication.

*	Unspecified energy type
e	Electricity
ng	Natural gas
st	Steam
ca	Compressed air
d	Diesel
c	Coal
hw	Hot water
Σ	The sigma notation is used to represent summation of all energy types. $\mathrm{ECP}(\Sigma) = \sum_{*} \mathrm{ECP}(*)$ Example: if observed baseline primary energy types are “e” and “ng”, then $\mathrm{ECP}(\Sigma) = \mathrm{ECP}(\mathrm{e}) + \mathrm{ECP}(\mathrm{ng})$

3. Modeled Period and 4. Period/Conditions of Interest – (Subscript)

b	Baseline period
i	Intermediate period
r	Reporting period
s	Standard conditions

5. Adjustment Indicator – (Superscript)

o	Observed (actual) value for the indicated time period of condition of interest
a	Adjusted value for the indicated time period or condition of interest

Energy Savings Notation

ESP_{TD}	Primary energy savings as determined by the top-down approach
ESP_{BU}	Primary energy savings as determined by the bottom-up approach

4. Facility Boundaries and Time Periods

4.1 Facility Boundaries

The organization shall establish facility boundaries for which an energy performance improvement value will be determined for SEP certification. The facility boundaries may be the same or a subset of the boundaries of the organization and its ISO 50001-energy management system. SEP requires accounting for all energy that crosses (into and away from) the facility boundaries.

Facility boundaries are considered three-dimensional, thus energy accounting shall include energy that enters the facility boundaries from the sky and ground if consumed at the facility (such as water heated by the sun and oil from an on-site well).

The facility boundaries shall not change between the baseline and reporting periods. Changes to the facility boundaries will result in the need for a non-routine adjustment (Section 5.3.2).

4.2 Selection of Time Periods

The determination of the SEP Energy Performance Indicator (SEnPI) value is based upon the energy consumption of the baseline and reporting periods. The baseline and reporting periods shall each be at least 12 consecutive months (1 year) long to account for variations in operations and seasonality.

The achievement period begins immediately following the conclusion of the baseline period and shall be at least 12 consecutive months (1 year) but not more than 120 consecutive months (10 years) in length. The length of the achievement period does not need to be a multiple of 12 months (i.e., 12 or 120 months long). The end of the reporting period and achievement period shall align.

Figure 1 provides an illustrative example of the relationship between a 12-month long baseline period, an achievement period of unspecified length, and 12-month long reporting period.

FIGURE 1: RELATIONSHIP BETWEEN BASELINE, REPORTING, AND ACHIEVEMENT PERIOD

The energy accounting shall be conducted from the beginning of the baseline period through the end of the achievement period. In some cases, too few data may be available within a 12-month period to achieve the required significance (Section 6.4) of adjustment models (Section 6). For these reasons, the length of the periods may span more than 12 months. If the data for the baseline and reporting periods span more than 12 months, the first month of each period shall be the same. The time from the baseline period to reporting period will be measured as the time from the midpoint of the baseline period to the midpoint of the reporting period.

5. Energy Accounting

5.1 Energy Consumption Data

The determination of energy performance improvement shall extend to all types of energy consumed within the facility boundaries. Subsequently, energy accounting includes the quantities of all energy types delivered into and away from the facility boundaries, using metered data as well as selected relevant variables that affect energy consumption. Use of existing utility meters may be sufficient to conduct energy accounting at many facilities. Special cases and requirements of energy accounting are presented in this section.

Data sufficient to determine the facility energy consumption during the baseline and reporting period shall be collected and recorded. This includes the quantity and energy content of each energy type and relevant variables included in the energy accounting.

Facility energy consumption is ultimately accounted for in terms of primary energy. The collection of delivered energy data will be of use in determining primary energy quantities.

Annex B provides details on how to convert various types of energy from typically available units to common units and from a delivered to primary energy basis. For information regarding energy types not listed in Annex B contact the SEP Administrator.

Data quantifying relevant variables that affect energy consumption shall be collected as part of the energy accounting.

The outputs of the energy accounting are used to determine energy consumption for the baseline and reporting periods. Data shall be collected at least monthly, though it may be necessary or desirable to collect data more frequently.

5.1.1 Primary and Delivered Energy

All energy types delivered into and away from the facility boundaries shall be accounted for on a primary energy basis. Conversion from delivered to primary energy accounts for the losses in generation, transmission, and distribution of various energy types. Conversion of delivered energy of an unspecified type to primary energy is expressed by Equation 1:

Eq (1) $\mathrm{ECP}(*) = \mathrm{m}(*) \times \mathrm{ECD}(*)$

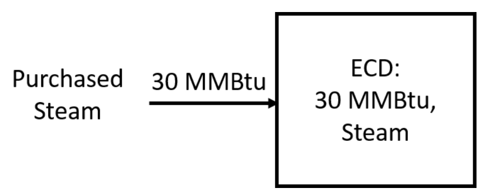
Where $\mathrm{m}(*)$ is the primary energy conversion factor for the unspecified type of energy. The primary energy conversion factor is comprised of two separate terms, the energy conversion multiplier ($\mathrm{ecm}(*)$) and the electricity generation multiplier ($\mathrm{egm}(*)$). Equation 2 expresses this relationship:

Eq (2) $\mathrm{m}(*) = \mathrm{ecm}(*) \times \mathrm{egm}(*)$

Annex B provides default energy conversion and electricity generation multipliers. Organizations have the option to use the multipliers in Annex B or may use site-specific multipliers if approved by the SEP Administrator. The choice of $\mathrm{m}(*)$, $\mathrm{ecm}(*)$, and $\mathrm{egm}(*)$ for each energy type shall be maintained and used consistently both in the baseline and reporting periods.

> NOTE: For a given type of energy multiple values of $\mathrm{m}(*)$ may be required. For example this may be the case when electricity is delivered to a facility via the grid as well as produced on-site from a photovoltaic panel. These multiple values of $\mathrm{m}(*)$ should be appropriately used in Equation 3.

EXAMPLE: A facility purchases and consumes 30 MMBTU of steam generated in a natural gas fired boiler at a neighboring facility. Annex B lists an $\mathrm{ecm}(*)$ of 1.33 and an $\mathrm{egm}(*)$ of 1.00 for “steam: fired boiler”, $\mathrm{m}(*)$ is thus 1.33 (1.33 x 1.00).



$$\mathrm{ECD(st)} = 30\ \mathrm{MMBTU}$$

$$\mathrm{ECP(st)} = (1.33\ \mathrm{x}\ 1.00)\ \mathrm{x}\ 30\ \mathrm{MMBTU} = 39.9\ \mathrm{MMBTU}$$

5.1.2 Measurement of Energy Consumption

The quantity of a particular type of energy that is consumed within the facility boundaries is defined by the net energy flow of that energy type across the facility boundaries. For each energy type included in the energy accounting, primary energy consumption shall be equal to or greater than zero. If energy consumption is calculated to be a negative value, it shall be accounted for as zero. In such cases care should be taken to ensure energy export and energy product are correctly accounted for.

Equation 3 describes how to calculate energy consumption on a primary energy basis. Conversion of delivered energy to primary energy shall be conducted with primary energy multipliers prior to determining the energy performance improvement. Figure 2 graphically illustrates this relationship.

Eq (3)
$$\text{ECP}(*) = \text{m}(*) \text{ x } [\text{E}(*) \text{ delivered to the facility } - \text{E}(*) \text{ delivered away as export}] + \text{m}(*) \text{ x } [\text{E}(*) \text{ onsite generation/extraction } - \text{E}(*) \text{ delivered away as product }] + \text{E}(*) \text{ drawn out of storage } - \text{E}(*) \text{ added to storage } - \text{E}(*) \text{ used as feedstock}$$

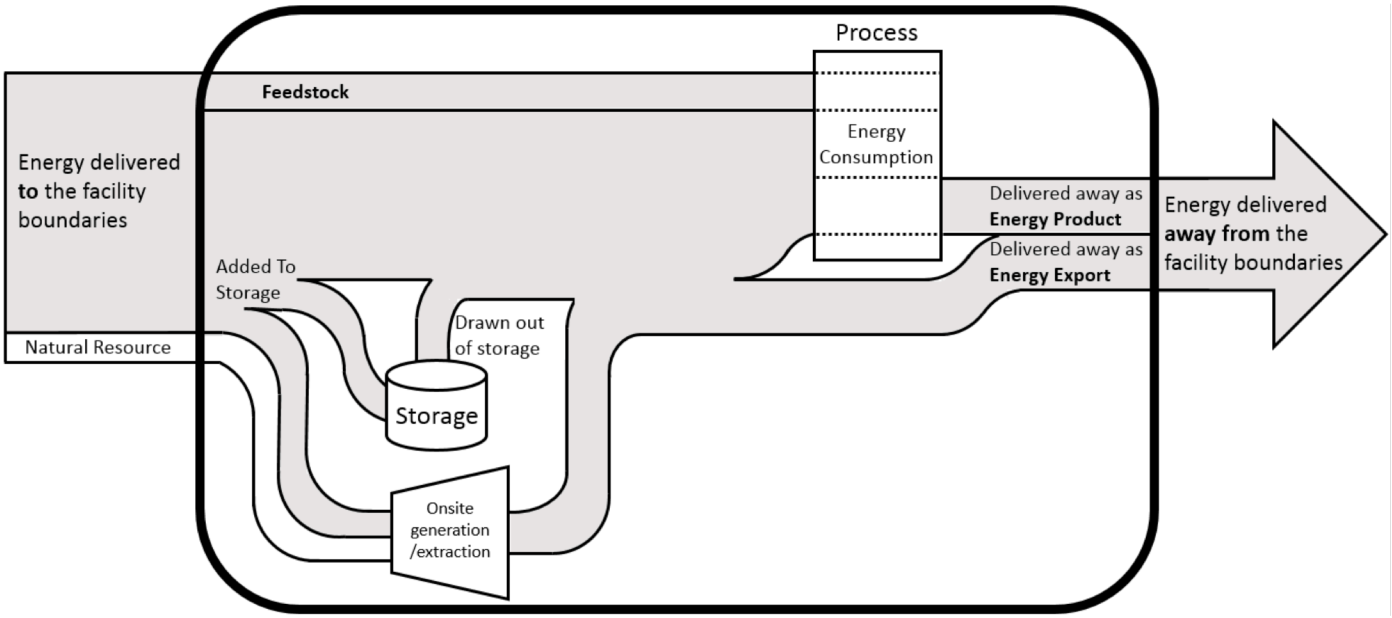


FIGURE 2: GENERIC ENERGY CONSUMPTION ACCOUNTING FLOW DIAGRAM

Data regarding the quantity of energy delivered into or away from the facility boundaries (delivered to the facility, delivered away as energy export, delivered away as energy product, or feedstock) may be available directly from meters or taken from a supplier invoice. Meters may directly report energy consumption values or physical properties such as pressure, temperature, mass, volumetric flow, and heating value that can be used to calculate energy consumption by using engineering equations and conversion factors.

The energy content of various energy types (the amount of energy potentially available within each unit of energy) may vary with factors such as density or heating value. Conversion factors from units as sold (e.g. cubic feet, gallons, or tons) to energy units may be available from the supplier. For most fuel types, information regarding the energy content per unit volume is typically available from the fuel supplier. The energy units for fuels shall be converted to the common energy unit being used for the energy accounting. The higher heating value (HHV) of energy types shall be used to calculate delivered energy units.

Data for energy consumption and relevant variables will frequently not be available for exact calendar months, nor for exactly aligning time intervals. For example, monthly production data may be reported on the first of the month, while utility data may be provided mid-month. Alignment of time intervals is preferred and may facilitate development of more representative adjustment models, but it is not required. Energy data may be collected at irregular intervals; for example, with bulk fuels if deliveries are unequally spaced in time.

5.1.3 Types of Energy with Relatively Insignificant Consumption

All energy types that cross the facility boundaries during the baseline and reporting periods shall be included in the energy accounting. Types of energy may be omitted from the energy accounting if these energy types account for in aggregate 5.0 percent or less of the facility's total primary energy consumption in each of the baseline and reporting periods. In calculating the percent of total consumption represented by an omitted energy type, both the energy consumption of the omitted energy type and total facility energy consumption shall be calculated on a primary energy basis. The determination to omit energy types may be based on measured or calculated data.

If the energy consumption of an energy type has been determined to be insignificant and will be omitted from the energy accounting, then it shall be omitted in both the baseline and reporting periods.

5.1.4 Special Cases in Energy Accounting

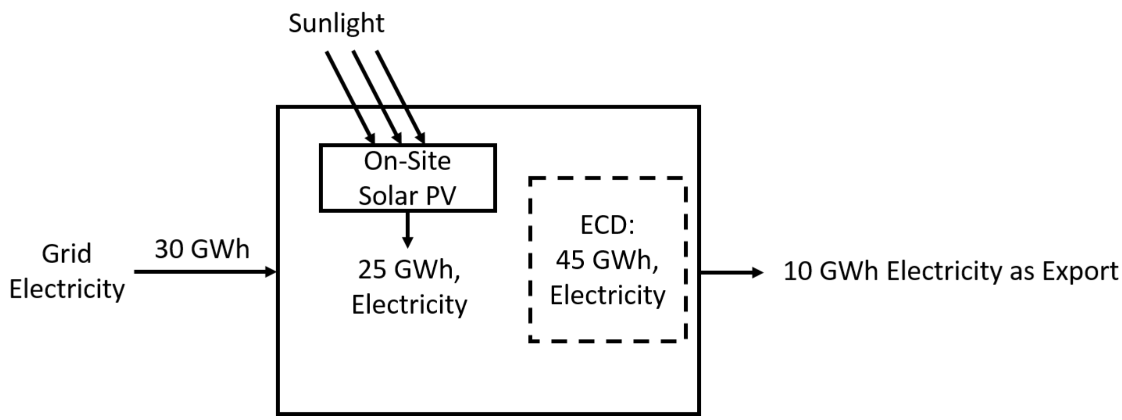
5.1.4.1 Energy Accounting of Energy Export and Energy Product

Energy delivered away from the facility boundaries shall be accounted for as either an energy export or energy product.

5.1.4.1.1 ENERGY EXPORT

The maximum allowable amount of energy export is equal to the quantity of energy delivered into the facility boundary of the same energy type such that a net zero level is reached on a primary energy basis. A facility may not be counted as a net negative consumer of any energy type. An energy export is converted to primary energy using the same multiplier as the energy type that was delivered to the facility (m1(*) in Equation 3).

EXAMPLE: A facility purchases 30 GWh of grid electricity and produces 25 GWh of electricity with on-site photovoltaic (PV) panels. The facility consumes 45 GWh and delivers 10 GWh away from the facility boundaries. The 10 GWh delivered away from the facility boundaries is treated as energy export. The energy streams are converted to energy consumption on a primary energy basis. See figure below.



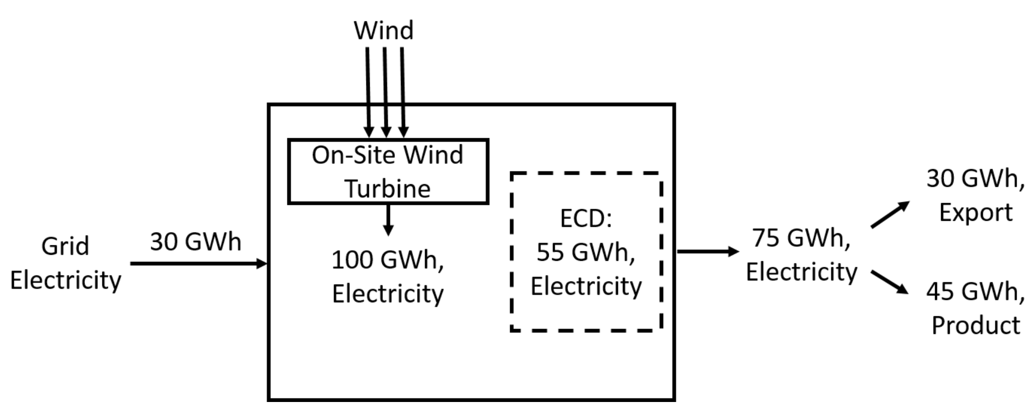
$$\mathrm{ECD(e)} = 30\ \mathrm{GWh} + 25\ \mathrm{GWh}\ -\ 10\ \mathrm{GWh} = 45\ \mathrm{GWh}$$

$$\mathrm{ECP(e)} = (3.0\ \mathrm{x}\ 30\ \mathrm{GWh}) + (1.0\ \mathrm{x}\ 25\ \mathrm{GWh}) - (3.0\ \mathrm{x}\ 10\ \mathrm{GWh}) = 85\ \mathrm{GWh}$$

5.1.4.1.2 ENERGY PRODUCT

For each energy type, if a net zero level is reached on a primary energy basis, any excess energy delivered away from the facility boundaries is accounted for as an energy product. This may result from a facility producing large quantities of on-site energy. Energy product shall be considered as a relevant variable for adjustment models. An energy product is converted to primary energy using the same multiplier as the energy type that was generated or extracted on-site within the facility boundaries (m2(*) in Equation 3).

EXAMPLE: A facility purchases 30 GWh of grid electricity and generates 100 GWh of electricity with on-site wind turbines. The facility consumes 55 GWh and delivers 75 GWh away from the facility boundaries. A maximum quantity of 30 GWh is treated as energy export. The remaining 45 GWh is treated as energy product. The energy streams are converted to energy consumption on a primary energy basis. See figure below.



$$\mathrm{ECD(e)} = 30\ \mathrm{GWh} + 100\ \mathrm{GWh} - 30\ \mathrm{GWh} - 45\ \mathrm{GWh} = 55\ \mathrm{GWh}$$

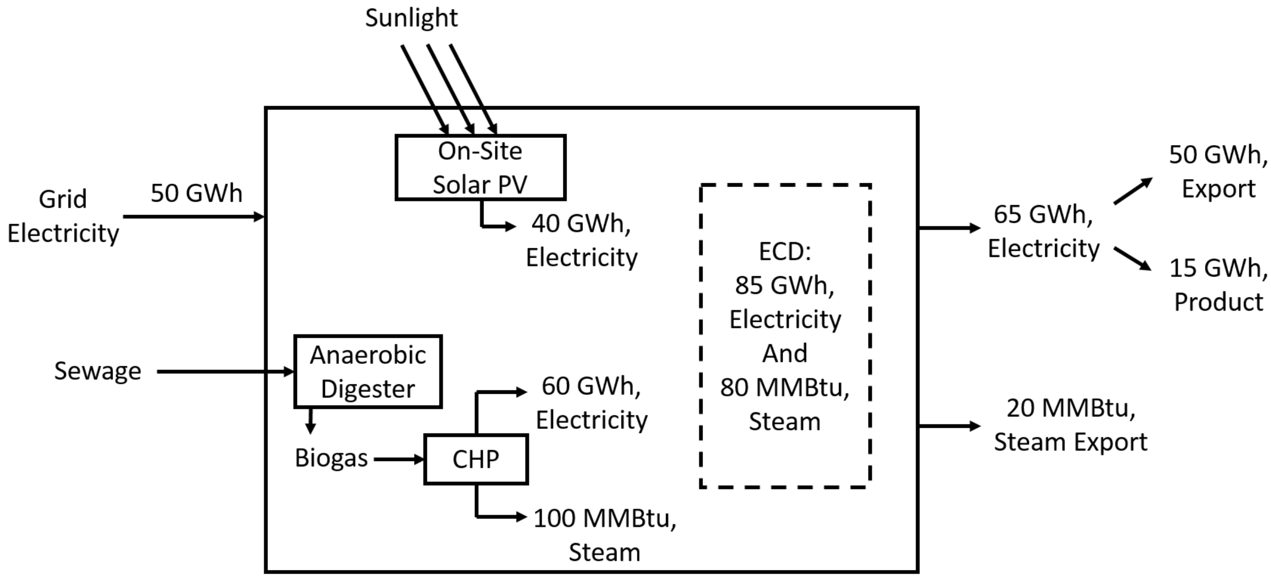
$$\mathrm{ECP(e)} = (3.0\ \mathrm{x}\ 30\ \mathrm{GWh}) + (1.0\ \mathrm{x}\ 100\ \mathrm{GWh}) - (3.0\ \mathrm{x}\ 30\ \mathrm{GWh}) - (1.0\ \mathrm{x}\ 45\ \mathrm{GWh}) = 55\ \mathrm{GWh}$$

5.1.4.2 On-site Extraction or Generation of Energy from Natural Resources

Energy from natural resources that are delivered into and consumed within or delivered away from the facility boundaries shall be included in the energy accounting. The point at which on-site extracted or generated energy is metered and accounted for may be selected by the organization so long as it is at a reasonable point along the extraction or generation process flow (e.g., a facility may choose to meter biogas flow and energy content or the resulting electricity and hot water generated from the utilization of the same biogas). This measurement point shall be consistent between the baseline and reporting periods. This allowance is made recognizing that the quantity of energy of some natural resources (e.g., photons or wind) or the energy derived thereof (e.g., biogas) may be difficult to meter. In such cases, the quantity of energy generated within the facility boundaries from the natural resource (e.g., AC electricity from the inverter of a PV panel system) may be metered and included in the energy accounting. Annex B provides multipliers for various types of energy extracted or generated from natural resources.

NOTE: While metering energy at a point along the extraction or generation process flow downstream of the facility boundaries may be simpler and more cost effective (e.g. metering hot water produced from a biogas fired boiler, rather than the biogas produced from a sewage fed digester), the affect of energy performance improvement actions implemented upstream of the point of metering may not be reflected in the calculated facility-wide energy performance improvement.

EXAMPLE: A wastewater treatment facility uses sewage to generate biogas, which is used to generate electricity and steam in a CHP system. The facility also purchases grid electricity, and generates on-site electricity with an array of PV panels. As the facility can not cost-effectively install meters to measure biogas flow and energy content, the facility decides to meter the electricity and steam coming out of the CHP system for energy accounting purposes. In one month, the biogas CHP system produces 60 GWh of electricity and 100 MMBTU of steam. The facility purchases 50 GWh of grid electricity and generates 40 GWh of on-site electricity with the PV panels. The facility consumes 85 GWh of electricity and delivers 65 GWh of electricity away from the facility boundaries. The facility consumes 80 MMBTU of steam and delivers 20 MMBTU away from the facility boundaries. The energy streams are converted to consumption on a primary energy basis. See Annex B for conversion and primary energy multipliers for electricity and steam, as well as the conversion to common units. See figure below.



Electricity: $\mathrm{ECD(e)} = 50\ \mathrm{GWh} + 60\ \mathrm{GWh} + 40\ \mathrm{GWh} - 50\ \mathrm{GWh} - 15\ \mathrm{GWh} = 85\ \mathrm{GWh}$

$$\mathrm{ECP(e)} = (3.0 \text{ x } 50\ \mathrm{GWh}) + (1.0 \text{ x } 60\ \mathrm{GWh}) + (1.0 \text{ x } 40\ \mathrm{GWh}) - (3.0 \text{ x } 50\ \mathrm{GWh}) - (1.0 \text{ x } 15\ \mathrm{GWh}) = 85\ \mathrm{GWh}$$

Steam: $\mathrm{ECD(st)} = 100\ \mathrm{MMBtu} - 20\ \mathrm{MMBtu} = 80\ \mathrm{MMBtu}$

$$\mathrm{ECP(st)} = (1.00 \text{ x } 100\ \mathrm{MMBTU}) - (1.00 \text{ x } 20\ \mathrm{MMBTU}) = 80\ \mathrm{MMBTU}$$

In the case that energy from an on-site extracted or generated natural resource is mixed with a delivered energy type, such as sawdust produced from the processing of timber mixed with coal in a boiler or natural gas mixed with on-site generated biogas in a gas turbine, both energy types shall be metered before they are consumed.

EXAMPLE: A sawmill uses sawdust along with coal in a boiler to raise steam within the facility boundaries. Coal deliveries are invoiced with the total weight and heating value. The sawdust is weighed and the heating value is determined from the Oak Ridge National Laboratory's *Biomass Energy Data Book*.[1] The energy consumption is calculated and converted to common units using information from Annex B.

5.1.4.3 Waste Heat Recovery

Waste heat recovery is considered an energy performance improvement action and not explicitly included in the energy accounting. Implementation of waste heat recovery may result in a reduction of energy

[1] Biomass Unit Conversion factors (heating values) shall be taken from the Oak Ridge National Laboratory *Biomass Energy Data Book – Appendix A* if possible. This reference also outlines a methodology for accounting for material moisture content.

consumption of one or more energy types that cross into the facility boundaries resulting in energy performance improvement. Alternatively, waste heat recovery may increase delivery of energy away from the facility boundaries.

EXAMPLE: In the baseline period a facility purchases 100 barrels of oil and uses 75 barrels to generate steam in a boiler and 25 barrels of oil to heat water for domestic purposes. After implementing a boiler waste heat recovery system used to preheat water fed to the water heater, the hot water heater only needs to consume 10 barrels of oil to meet the hot water demand. Assuming all other factors remain constant, the reporting period energy consumption will be 15 barrels of oil less than in the baseline period.

5.1.4.4 Feedstock and Resulting Energy Types

In some instances, energy delivered to the facility boundaries may be used as a feedstock rather than consumed as energy. The portion of an energy type used as a feedstock shall be subtracted from the delivered energy. The commodity that is being produced from the feedstock shall be considered as a relevant variable in the energy consumption adjustment model.

Any energy types resulting from the processing of feedstock (e.g., process gas produced during the refining process, heat generated by an exothermic reaction, biogas generated from sewage) that are consumed within or delivered away from the facility boundaries shall be included in the energy accounting.

EXAMPLE: A facility purchases 100 barrels of oil and uses 75 barrels of oil to produce gasoline, which is sold as a commodity, while consuming the other 25 barrels of oil within the facility boundary in a boiler. As a byproduct of the refining process, 50 MMBTU of process gas is produced on-site. This process gas is consumed within the facility boundaries. The energy accounting shall include 25 barrels of oil and 50 MMBTU of process gas. The production quantity of gasoline shall be considered as a relevant variable in the energy consumption adjustment model.

5.2 Expressing Energy Consumption in Common Units

A common energy unit (e.g., kWh, BTU, Mtoe, Joules) shall be selected and used consistently as part of the energy accounting. A common energy unit allows for comparison and aggregation of the absolute and relative consumption of multiple energy types. All conversation factors used to convert various units to the chosen common energy unit shall be used consistently for the baseline and reporting periods, both the top-down and bottom-up calculations, and maintained. Annex B lists conversion factors useful for converting from commonly measured energy units to MMBTU.

5.3 Energy Consumption and Non-Routine Adjustments for the Time Periods of Interest

5.3.1 Establishing the Baseline and Reporting Period Energy Consumption

For each type of energy included in the energy accounting, an unadjusted energy baseline is established for the baseline period. Additionally, an unadjusted total energy baseline for the facility is established by summing the energy consumption of all energy types during the baseline period.

Similarly, unadjusted energy consumption for each type of energy consumed within the facility boundaries shall be established for the reporting period. The total of unadjusted energy consumption during the reporting period for the facility is then established by summing the energy consumption across all energy types in the reporting period.

5.3.2 Non-Routine Adjustments

Energy consumption may be affected by relevant variables and static factors during the baseline and reporting periods. Normalization through adjustment modeling is used to account for regular changes in relevant variables. Non-routine adjustments are made to the observed (actual) energy consumption in the baseline and/or reporting periods if one or both of the following have occurred:

1. If static factors have changed during the achievement period
2. If relevant variables have been subject to unusual changes in at least one of the two periods

Examples of events that might require a non-routine adjustment include the following:

- A supplier goes out of business, and an equivalent raw material is not available. A process modification is needed to use a different type of raw material. No data exist for baseline-period operating conditions with the new type of raw material.
- Processes are outsourced, enhancing profitability and decreasing energy consumption.
- A facility increases the amount of biomass consumed as energy. Use of biomass is encouraged by SEP, however, the efficiency of a biomass combustion system is typically less than that of systems that utilize conventional fossil fuels. If a participating facility shifts to using a greater amount of biomass, a non-routine adjustment may be used to compare reporting period to baseline period energy consumption as if the extent of biomass consumption were the same in both periods.
- Business acquisition occurs which results in data not being available or limits on the data availability for the period prior to the acquisition.

Any numeric inputs to non-routine adjustment calculations shall be based on observed, measured, or metered data.

Non-routine adjustments are typically based on an engineering analysis to calculate energy consumption in the baseline and reporting periods as if static factors were at the same condition in both periods. In this case, the adjustment will be to calculate baseline period energy consumption as if the reporting period condition of the static factors had been the same as in the baseline period.

The method for making the non-routine adjustment and the rationale for that method shall be maintained, including the general reasonableness of the methodology and calculations, the adequacy of the metering and monitoring methodologies, and conformance of the calculations applied. Non-routine adjustments may be used, but only with SEP Administrator approval that has been obtained prior to the verification of energy performance improvement. Non-routine adjustments shall be identified in the application to the SEP Administrator and as part of the verification of energy performance improvement. The method for making the non-routine adjustment and the rationale for that method must be recorded.

5.4 Relevant Variables

Relevant variables are variables that directly affect the amount of energy consumed within the facility boundaries and are used to normalize energy consumption as part of an adjustment model. When developing an adjustment model, care shall be taken to both (1) avoid omitting relevant variables that affect energy consumption and (2) include variables that are not relevant to energy consumption. Variables are excluded from the model if there is no logical mechanism by which the variable would affect the consumption of the energy type(s) being modeled.

Data quantifying relevant variables is collected as part of the energy accounting process. Relevant variables shall be physical quantities, characteristics, or conditions. Financial metrics or metrics that include a financial component, such as product price or energy costs are not allowed because they lack a physical relationship to energy consumption.

EXAMPLES: production quantities, equivalent products, number of batches, heating degree-days, humidity, occupancy, hours worked, raw material characteristics, and guests served.

Certain relevant variables shall be included in the energy accounting and considered when developing adjustment models:

For any type of facility (industrial and commercial) the following shall be considered:

- Activity level (e.g., occupancy, operating hours, production level, and equivalent products)
- Weather (e.g., heating degree-day, cooling degree-day, and humidity)

5.5 Data Sources and Quality

All data sources used as part of the energy accounting, including those for energy consumption and relevant variables, shall be of sufficient quality to be verifiable by the SEP Performance Verifier. Only data taken from precise control and/or measurement systems, such as revenue utility meters and regularly calibrated submeters, are considered verifiable. Quantification of energy consumption or of a relevant variable via subtraction of readings from two or more calibrated meters is acceptable.

Calibration of meters shall follow manufacturer's recommendations. Calibration records and records of repairs to calibrated meters shall be maintained. However, calibration records for utility meters are not the responsibility of the organization and do not need to be maintained. Solid fuel measurements from scales are acceptable provided that a qualified worker (internal or external to the organization) regularly calibrates the scale according to manufacturer recommendations or United States Department of Transportation (US DOT) requirements.

Reports previously submitted to state or federal government agencies (such as the United States Environmental Protection Agency (US EPA) for emissions or the US DOT for scales) are of sufficient quality for SEP energy accounting.

Weather data shall be actual weather data from the baseline and reporting periods, from published government sources, such as primary National Oceanic and Atmospheric Administration (NOAA) weather stations, or from a calibrated weather meter within close enough proximity to the facility to reflect the weather conditions at the facility.

Energy consumption and relevant variable data shall be screened for anomalous values that are not representative of typical operating conditions. If high variability is characteristic of the operation, outliers do not necessarily need to be removed. However, the effect of outliers on the reliability of the model estimates and the reason for removing them is maintained as a record.

If an anomalous value is found, reasons for the anomaly shall be identified if possible. If the anomaly is determined to be a data error, the error shall be corrected if possible; otherwise deleted from the model.

6. Normalization for Relevant Variables – Adjustment Modeling

6.1 General Principles of Normalization

Normalization of energy consumption through the use of adjustment models shall be made so that baseline and reporting periods can be compared as if all relevant variables were the same in the two periods. Normalized baseline period and/or reporting period energy consumption are calculated using one or more adjustment models.

6.2 Methods of Normalization

Four methods are allowed to create adjustment models. The same adjustment model method shall be used for each energy type consumed within the facility boundaries.

6.2.1 Forecast Normalization

Forecast normalization results in a model of baseline period energy consumption that is applied to the reporting period relevant variable values to calculate adjusted baseline period energy consumption

($\mathrm{ECP}(\Sigma)^{a}_{b|r}$) for comparison with observed (actual) reporting period energy consumption ($\mathrm{ECP}(\Sigma)^{o}_{r}$). The adjusted baseline period energy consumption is an estimate of the energy consumption that would have been expected at reporting period-relevant variable values, if the baseline operating systems and practices were still in place during the reporting period.

6.2.2 Backcast Normalization

Backcast normalization results in a model of reporting period energy consumption that is applied to the baseline period-relevant variable values to calculate adjusted reporting period energy consumption ($\mathrm{ECP}(\Sigma)^{a}_{r|b}$) for comparison to observed (actual) baseline period energy consumption ($\mathrm{ECP}(\Sigma)^{o}_{b}$). The adjusted reporting period energy consumption is an estimate of the energy consumption that would have been expected at baseline period relevant variable values, if the reporting period operating systems and practices were in place during the baseline period.

6.2.3 Standard Condition Normalization

Standard condition normalization results in two adjustment models: one of baseline period energy consumption and one for reporting period energy consumption. Standard conditions are applied to each of the models to calculate adjusted energy consumption values ($\mathrm{ECP}(\Sigma)^{a}_{r|s}$) and ($\mathrm{ECP}(\Sigma)^{a}_{b|s}$). The adjusted energy consumption for each period is the estimated energy consumption that would have been expected at a standard set of conditions (relevant variable values).

6.2.4 Chaining Normalization

Chaining normalization is a composite of the forecast and backcast normalization methods. The chaining method may be used if there is an intermediate period that is of the same length of, and is in between the baseline and reporting periods for which a model can be developed. In this case, the intermediate period model is used to backcast to the baseline period year and forecast to the reporting period year.

Chaining normalization may be useful if the reporting period conditions for energy consumption and relevant variables are outside the range of conditions of the baseline period model, and the baseline period conditions are outside the range of conditions of the reporting period, or a model cannot be developed for either the reporting or baseline periods.

6.2.5 Summary of Normalization Methods

TABLE 1: SUMMARY OF NORMALIZATION METHODS

	Forecast	Backcast	Standard Conditions	Chaining: Baseline to Intermediate	Chaining: Intermediate to Reporting
Reporting period energy consumption	Actual reporting period energy consumption	Reporting period model using baseline period conditions	Reporting period model using standard conditions	Not applicable	Actual reporting period energy consumption
Baseline period energy consumption	Baseline period model using reporting period conditions	Actual baseline period energy consumption	Baseline period model using standard conditions	Actual baseline period energy consumption	Not applicable
Intermediate period energy consumption	Not applicable	Not applicable	Not applicable	Intermediate period model using baseline period conditions	Intermediate period model using reporting period conditions
Operating characteristics the model is representing	Baseline period operating systems and practices	Reporting period operating systems and practices	Operating systems and practices using standard conditions	Intermediate period operating systems and practices	Intermediate period operating systems and practices

6.3 Determination of Normalized Energy Consumption

6.3.1 General

Use of the forecast, backcast, standard conditions, or the chaining normalization methods requires computation of adjusted energy consumption with an adjustment model. An adjustment model is created using observed (actual) energy consumption and relevant variable data (as determined using the energy accounting requirements described in Section 5) from either the baseline or reporting period (or an intermediate period in the case of chaining). The period whose data is used to create the model is the adjustment model period. The adjustment model is then applied to conditions (relevant variable values) from a different period, or to standard conditions. The result is adjusted energy consumption representing the systems and operations of the adjustment model period, at the conditions (relevant variable values) of the application conditions.

6.3.2 Creating an Adjustment Model

An adjustment model shall be created that describes energy consumption as a function of relevant variables for each energy type included in the energy accounting. The starting date and duration of the period for which adjustment models for all energy types are created shall be the same. The resulting adjusted energy consumption values for each energy type are then summed to determine an adjusted total energy consumption value.

However, in some instances it is advantageous to aggregate the consumption of multiple energy types prior to modeling (e.g. electricity consumption includes multiple sources such as the grid and on-site PV panels). If the following three conditions are met then the energy consumption of one more energy types may be summed together prior to being modeled in aggregate:

1. All energy consumption units are converted to a common energy unit (e.g., BTU, Joules, kWh) using document multipliers and are converted to primary energy.
2. The period during which the data to be summed was collected is the same for all energy types.
3. The model for the combined energy types satisfies validity requirements (Section 6.4).

A minimum of 12 months of data are required when creating an adjustment model. The data used to create an adjustment model may be at any regular frequency of observation from metering data for each energy type and relevant variable as was collected as part of the energy accounting provided the model significance testing criteria of Section 6.4 are met. Data reported at intervals of one hour or less may be summed or averaged to weekly or monthly totals.

Adjustment model forms that may be used are described below. The selected adjustment model form shall be consistent with an expected relationship based on prior operating experience, or other sound basis for how each relevant variable is expected to affect energy consumption. The rationale for selection of the model form shall be given, along with statistical goodness-of-fit diagnostics required in Section 6.4. The following model forms may be applied for any approved adjustment modeling methods.

Model Form 1: Ratio of Energy Consumption to a Single Relevant Variable

This simple model form may be used when energy consumption is affected by a singular relevant variable and there is a negligible level of base load energy consumption. If this model form is to be used, the relevant variable selected shall relate to the operations of the facility. The model takes the form:

Eq (4) $$ECP = bx$$

where *x* is the relevant variable quantity and *b* is the primary energy consumption per unit of that relevant variable. The coefficient *b* is calculated from energy consumption and the single relevant variable data over the period for which the model is being developed, sometimes called the *energy intensity*.

Model Form 2: Linear Regression

Linear regression adjustment models allow for multiple relevant variables that affect energy consumption to be taken into account. The model takes the form:

Eq (5) $ECP(*) = b_0 + b_1x_1 + b_2x_2 + \ldots + b_kx_k$

where x_i is the relevant variable quantity, b_0 is the base load primary energy consumption not related to relevant variables, and $b_{i>0}$ is the incremental energy consumption per unit of that relevant variable (coefficient).

Model Form 3: Complex Regression

Two complex regression model forms may be used, but only with SEP Administrator approval.

- Polynomial regression model: This is a form of linear regression including terms in integer powers of the individual relevant variables and products of these variables. For example, for a second-order polynomial in x_1, x_2, x_3, terms would include any or all of x_1^2, x_2^2, x_3^2, x_1x_2, x_2x_3, and x_3x_1 in addition to x_1, x_2, x_3. A second-order polynomial model can serve as an approximation to a more complicated nonlinear model.
- General nonlinear regression model: This form allows terms that are nonlinear in the estimated coefficients. For example, model terms could include x^β with an exponent β to be determined by the regression.

For either kind of complex model, one or more of the following rationales for the particular complex model specification used shall be provided:

- The model specification corresponds to a known underlying physical/engineering relationship, or a simplification of a known underlying physical/engineering relationship.
- The model specification is a polynomial approximation (such as a quadratic fit) to a more complicated theoretical form.
- The model specification empirically has been tested and found to meet the validity criteria of Section 6.4, not only for the particular data series of the baseline or reporting periods, but also over other time periods or data sets.
- When applying the validity requirements for complex regression models, each higher-power term shall satisfy all of the requirements described for individual variables in the model.

6.4 Validity Requirements

Regardless of which normalization method and which model form is used, adjustment models used to calculate adjusted energy consumption shall satisfy the validity requirements described in this section.

6.4.1 Model Validity Testing

For the adjustment model to be considered valid, all the following shall be demonstrated:

- An F-test for the overall model fit shall have a p-value less than 0.10 (i.e., the overall fit of the adjustment model is statistically significant greater than the 10% significance level).
    - An F-test is used to test the overall statistical significance of a regression model, regardless of the number of variables used in the regression model. The F-test compares a particular regression model against an intercept-only model. If the p-value calculated from the F-statistic and model degrees of freedom is less than 0.10, then one can reject the intercept-only model in favor of the regression model. The regression model is considered statistically significant (i.e. at least one of the regression variables used in the model has a “significant” effect on energy consumption)
- All included relevant variables in the model shall have a p-value less than 0.20.
- At least one of the relevant variables in the model shall have a p-value less than 0.10.
- The coefficient of determination (R^2) for the regression shall be 0.50 or greater.
- The selection of relevant variables in the adjustment model and the subsequently determined relevant variable coefficients are consistent with a logical understanding of the energy use and energy consumption of the facility.

6.4.2 Validity of Applying Adjustment Models to Relevant Variables

The validity of applying adjustment models to relevant variables shall be tested through quantitative and qualitative tests.

6.4.2.1 Valid Quantitative Range of Model Relevant Variables

For the adjustment model to be valid for calculating adjusted energy consumption, the mean of the adjustment model’s relevant variables used to calculate the adjusted energy consumption shall fall within either:

- the range of observed relevant variable data that went into the model, or
- three standard deviations from the mean of the relevant variable data that went into the model.

Any outliers excluded when creating the adjustment model shall also be excluded when calculating the valid quantitative range of model-relevant variables.

6.4.2.2 Valid Qualitative Factors

For the adjustment model to be valid for calculating adjusted energy consumption, the following qualitative factors shall also be true of the adjustment model period and the application conditions.

- No substantial difference between the two periods in product types.
- Meters used were functioning, calibrated and maintained as appropriate.

6.5 Creating Adjustment Models for Different Operating Modes

If a facility has two or more different modes of operation that it switches between either regularly (e.g., seasonally) or irregularly, separate adjustment models with unique coefficients for relevant variables may need to be created for each operating mode. This multi-mode modeling approach may result in fewer data points being available to create each adjustment model.

However, in some cases a singular adjustment model might be created by incorporating additional relevant variables that account for the different energy consumption patterns for the different operational modes instead of using the multi-mode adjustment modeling approach.

EXAMPLE: Rather than creating different adjustment models for 1-shift and 2-shift operations, a relevant variable corresponding to daily operating hours of key process lines are included to create a single adjustment model that reflects both operational practices.

If a multi-mode adjustment model is used, the adjusted energy consumption shall be calculated by applying the model for each mode to the corresponding conditions. If the conditions for calculating adjusted energy consumption vary over the period, the model corresponding to the mode for each part of the period shall be used to calculate the adjusted consumption for that part of the period. If the time the facility spends in each mode is irregular, the typical time spent in each mode shall be identified, and the adjusted consumption shall be calculated weighting the results from each mode in proportion to the typical time in each mode. The same proportions shall be applied for the baseline and reporting periods.

If unusual operating conditions are the result of an anomaly, an adjustment model may be developed that excludes the anomalous data. The normal and unusual operating conditions are then treated as two different modes of operation. The proportion of time the facility is in the unusual operating condition is estimated from the data. The model without the anomalous data points describes normal operating conditions. A separate model is developed with the unusual operating conditions if there are enough observations, or a simple average is taken for these conditions.

A particular type of data outlier for industrial facilities may be a result of shutdown periods, when production is zero. If a valid model can be developed that includes these conditions as well as more typical operating conditions, the shutdown period does not have to be treated separately. The single model can be used and applied to determine adjusted energy consumption for a period that includes normal operation, shutdown, or both. If a valid model cannot be estimated to cover all of the baseline period or reporting period, normal operations and shutdown can be treated as separate modes of operation with separate models combined into a multi-mode model.

6.6 Facility Subsets

If possible, observed or adjusted energy consumption for each energy type will be determined based upon the facility boundaries. If this is not possible, an alternative is to divide the facility into subsets for which the energy accounting and adjustment modeling is performed separately for each energy type. Each part of the facility shall be included in one and only one subset. Adjustment modeling of a subset requires historical consumption and relevant variable data on that subset in isolation. Facility-wide adjusted energy consumption for each energy type is calculated by summing the energy consumption of each subset together. If this is done, the same normalization method and adjustment model form shall be used to determine adjusted energy consumption for each of the subsets.

EXAMPLE: Energy accounting for multiple major production lines is performed with submeters and adjusted energy consumption is modeled separately for each subset. All other facility energy consumption is accounted for together by subtracting the energy consumption of the projection line subsets from the facility utility meters.

7. Calculation of Energy Performance Improvement for the SEP Program

7.1 Calculating the SEP Energy Performance Indicator

For SEP, the Energy Performance Indicator (EnPI) used to measure energy performance improvement is the SEP Energy Performance Indicator (SEnPI). The SEnPI is the ratio of the facility-wide, reporting period total primary energy consumption and baseline period total primary energy consumption, where the energy consumption of one or both periods is adjusted so that they correspond to consistent conditions of relevant variables (Equation 6). A SEnPI value less than 1.0 indicates that energy performance has improved.

Eq (6) $$\mathrm{SEnPI} = \frac{\mathrm{ECP}(\Sigma)_\mathrm{r}}{\mathrm{ECP}(\Sigma)_\mathrm{b}}$$

Where $\mathrm{ECP}(\Sigma)_\mathrm{r}$ and/or $\mathrm{ECP}(\Sigma)_\mathrm{b}$ have been adjusted depending upon the normalization method utilized.

The chained SEnPI from the baseline period to the reporting period is the product of the backcast EnPI from the baseline period to the intermediate period ($\mathrm{EnPI}_{\mathrm{b|i}}$) and the forecast EnPI from the intermediate period to the reporting-period ($\mathrm{EnPI}_{\mathrm{i|r}}$) (Equation 7).

Eq (7) $$\mathrm{SEnPI} = (\mathrm{EnPI}_{\mathrm{i|b}})(\mathrm{EnPI}_{\mathrm{i|r}})$$

Table 2 lists the notation used to refer to the actual and adjusted energy consumption for each method, as well as the data used to create the model and the data used to apply the model.

TABLE 2: USE OF OBSERVED AND ADJUSTED ENERGY CONSUMPTION FOR THE VARIOUS NORMALIZATION METHODS

		Primary Methods			Chaining Method	
		Forecast	Backcast	Standard Conditions	Baseline to Intermediate Period	Intermediate to Reporting Period
Energy Consumption Quantity	Reporting Period $\mathrm{ECP}(\Sigma)_r$	Observed (actual) $\mathrm{ECP}(\Sigma)_r^o$	Adjusted to baseline conditions $\mathrm{ECP}(\Sigma)_{r\mid b}^a$	Adjusted to standard conditions $\mathrm{ECP}(\Sigma)_{r\mid s}^a$	NA	Observed (actual) $\mathrm{ECP}(\Sigma)_r^o$
	Intermediate Period $\mathrm{ECP}(\Sigma)_i$	NA	NA	NA	Adjusted to baseline conditions $\mathrm{ECP}(\Sigma)_{i\mid b}^a$	Adjusted to reporting period conditions $\mathrm{ECP}(\Sigma)_{i\mid r}^a$
	Baseline Period $\mathrm{ECP}(\Sigma)_b$	Adjusted to reporting period conditions $\mathrm{ECP}(\Sigma)_{b\mid r}^a$	Observed (actual) $\mathrm{ECP}(\Sigma)_b^o$	Adjusted to standard conditions $\mathrm{ECP}(\Sigma)_{b\mid s}^a$	Observed (actual) $\mathrm{ECP}(\Sigma)_b^o$	NA
SEnPI Equation		$\frac{\mathrm{ECP}(\Sigma)_r^o}{\mathrm{ECP}(\Sigma)_{b\mid r}^a}$	$\frac{\mathrm{ECP}(\Sigma)_{r\mid b}^a}{\mathrm{ECP}(\Sigma)_b^o}$	$\frac{\mathrm{ECP}(\Sigma)_{r\mid s}^a}{\mathrm{ECP}(\Sigma)_{b\mid s}^a}$	$\frac{\mathrm{ECP}(\Sigma)_{i\mid b}^a}{\mathrm{ECP}(\Sigma)_b^o} \times \frac{\mathrm{ECP}(\Sigma)_r^o}{\mathrm{ECP}(\Sigma)_{i\mid r}^a}$	

7.2 Calculating the Energy Performance Improvement Percentage

The energy performance improvement percentage is used with the *SEP Certification Protocol* and *SEP Scorecard* to determine SEP certification level.

Eq (8) Energy performance improvement (%) = (1-SEnPI) x 100

8. Bottom-Up Comparison

8.1 Purpose of the Bottom-Up Comparison

The top-down analysis yields an energy performance improvement, expressed as a percentage. The bottom-up comparison confirms that the top-down energy performance improvement percentage could reasonably have resulted from the known actions that were taken to improve the energy performance. The estimated energy savings corresponding to the top-down energy performance improvement percentage is compared to the sum of estimated energy savings from discrete energy performance improvement actions taken at the facility over the achievement period. Actions taken to improve energy performance include changes in procedures, behavior, operations, equipment, and processes.

8.2 Register of Implemented Energy Performance Improvement Actions (Register)

Each facility shall develop and maintain a *Register of Implemented Energy Performance Improvement Actions (Register)* to provide the necessary documentation for the bottom-up comparison. The Register is essentially a running list of implemented actions undertaken during the achievement period that supports the energy performance improvement level claimed. The organization shall list these actions regardless of whether the action is associated with ISO 50001 Action Plans or Significant Energy Uses. The Register shall reflect energy savings over the reporting period; typically, this will be annual savings.

The Register shall include at least one energy performance improvement action for each type of energy included in the top-down determination of energy performance improvement.

For each energy performance improvement action listed, the facility shall provide the following:

- Description of energy performance improvement action.
- Anticipated annual[2] site energy savings by energy source:
    - Describe operating conditions for which energy savings are calculated.
    - Describe the starting point or baseline situation that was improved upon (e.g., equipment, systems, practices, or procedures).
- Anticipated annual primary energy savings by energy source.
- Link or location of action plan documentation, as appropriate.
- Date action implementation was completed.
- Annual site energy savings by energy source for the reporting period[3], determined after action implementation is complete.
- Annual *primary* site energy savings by energy source for the reporting period, determined after action implementation is complete
- Method(s) used to determine annual energy savings.
    - E.g., assumptions used, measurements taken, calculations, and conversion factors.

8.3 Conducting the Bottom-Up Comparison

The bottom-up comparison consists of the following steps:

[2] Energy savings are listed as annual, assuming a 12-month reporting period. The energy savings shall be over the same number of months as the baseline and reporting periods.
[3] If the action was taken during the reporting period, annual energy savings may be pro-rated to align with the implementation date.

1. The facility shall provide a *Register of Implemented Energy Performance Improvement Actions* (Register) as described in Section 8.2.
2. For each energy type, the facility will sum the actual annual energy savings on a delivered energy basis from the Register for the achievement period.
3. For each energy type, the facility will convert the total actual annual delivered energy savings from Step 2 to total acutal annual primary energy savings.
4. The facility will sum the total actual annual primary energy savings across all energy types. This sum is the bottom-up energy savings estimate, $\mathrm{ESP_{BU}}$.
5. The facility will determine the top-down energy savings estimates from the top-down energy performance improvement percentage. This determination depends on the normalization method used.

   For the Forecast method:

   Eq (9) $\mathrm{ESP_{TD}} = \mathrm{ECP}(\Sigma)^{\mathrm{a}}_{\mathrm{b|r}} - \mathrm{ECP}(\Sigma)^{\mathrm{o}}_{\mathrm{r}}$

   For the Backcast method:

   Eq (10) $\mathrm{ESP_{TD}} = \mathrm{ECP}(\Sigma)^{\mathrm{o}}_{\mathrm{b}} - \mathrm{ECP}(\Sigma)^{\mathrm{a}}_{\mathrm{r|b}}$

   For the Standard Conditions method:

   Eq (11) $\mathrm{ESP_{TD}} = \mathrm{ECP}(\Sigma)^{\mathrm{a}}_{\mathrm{b|s}} - \mathrm{ECP}(\Sigma)^{\mathrm{a}}_{\mathrm{r|s}}$

   For the Chaining method:

   Eq (12) $\mathrm{ESP_{TD}} = (\mathrm{ECP}(\Sigma)^{\mathrm{o}}_{\mathrm{b}} - \mathrm{ECP}(\Sigma)^{\mathrm{a}}_{\mathrm{i|b}}) + (\mathrm{ECP}(\Sigma)^{\mathrm{a}}_{\mathrm{i|r}} - \mathrm{ECP}(\Sigma)^{\mathrm{o}}_{\mathrm{r}})$

   The facility will divide actual bottom-up energy savings estimate by the top-down energy savings estimate to determine the "bottom-up to top-down reconciliation factor:

   Eq (13) $\mathrm{RF} = \frac{\mathrm{ESP_{BU}}}{\mathrm{ESP_{TD}}}$

   The facility will determine the verified energy performance improvement percentage as follows:

   - If the bottom-up to top-down reconciliation factor (RF) is greater than or equal to 0.80, the verified energy performance improvement percentage shall be the top-down energy performance improvement percentage.
   - If the bottom-up to top-down reconciliation factor (RF) is less than 0.80, the verified energy performance improvement percentage shall be the top-down energy performance improvement percentage multiplied by RF.

6. The facility will provide sufficient information to show the reasonableness of each energy performance improvement action calculation.

7. Using the information provided the SEP Performance Verifier will:

   - Confirm that each type of energy included in the top-down determination of energy performance improvement is represented by at least one action in the Register.
   - Select a sample of Energy Performance Improvement Actions and spot check calculations for reasonableness. This is not intended to be a 100% sample of the actions taken but rather a representative sample based on the action complexity and risk associated with the verification activities. The sample will take into account the methods used to determine savings during the most recent achievement period (e.g. calculation, measurement, estimation), the monitoring and measurement activities related to the actions, and the timeframe of the audit.
   - Remove improvement actions from the Register that were not or could not reasonably be demonstrated to improve energy performance.
   - Confirm the final top-down energy performance improvement percentage (ESP_{TD}) multiplied by RF per above.

   NOTE: While actions taken in Step 7 may result in a change to the final SEnPI, these actions shall not be documented as audit nonconformities.

   EXAMPLE: A site has 12 actions taken over the baseline, achievement and reporting period, and 8 of those actions are in the achievement period. Three actions are related to objectives and targets set by the site and include measurement activities verified during the ISO 50001 part of the audit. For the remaining five actions, two are calculations, two are estimations from a contractor, and one has measurement data from a submeter.

   The SEP Performance Verifier sample includes one estimation, one calculation and the one action using the submeter. The three actions related to objectives and targets have a lower risk due to the other audit activities and the representative nature of the sample taken helps to ensure lack of bias, and cross representation of the methods used by the site have been evaluated. The verification is for the current SEP Application and does not include evaluation of previous achievement periods.

9. References

The following standard references apply to the *SEP M&V Protocol*.

- ISO 50001
- ANSI/MSE 50021

- ISO 17747
- ISO 50003
- ANSI/MSE 50028
- *Superior Energy Performance Scorecard*
- *Superior Energy Performance Certification Protocol*

Annex A - Informative: Reference Notation used in this Protocol

All reference notation uses are listed in this annex. This list does not preclude the utilization of other nomenclature combinations but is simply an informative listing.

TABLE 3 – REFERENCE NOTATION

$\mathrm{E}(*)$	Quantity of energy of an unspecified type
$\mathrm{ECD}(*)$	Delivered energy consumption of an unspecified energy type
$\mathrm{ECP}(*)$	Primary energy consumption of an unspecified energy type
$\mathrm{ECP}(\mathrm{e})$	Primary energy consumption of the energy type “electricity”
$\mathrm{ECP}(\mathrm{ng})$	Primary energy consumption of the energy type “natural gas”
$\mathrm{ECP}(\mathrm{st})$	Primary energy consumption of the energy type “steam”
$\mathrm{ECP}(\Sigma)$	Primary energy consumption of all energy types
$\mathrm{ECP}(\Sigma)_{\mathrm{b}}^{\mathrm{o}}$	Observed (actual) baseline period energy consumption
$\mathrm{ECP}(\Sigma)_{\mathrm{r}}^{\mathrm{o}}$	Observed (actual) reporting period energy consumption of all energy types
$\mathrm{ECP}(\Sigma)_{\mathrm{b\|r}}^{\mathrm{a}}$	Modeled baseline period primary energy consumption adjusted to reporting period conditions
$\mathrm{ECP}(\Sigma)_{\mathrm{r\|b}}^{\mathrm{a}}$	Modeled reporting period primary energy consumption adjusted to baseline period conditions
$\mathrm{ECP}(\Sigma)_{\mathrm{b\|s}}^{\mathrm{a}}$	Modeled baseline period primary energy consumption adjusted to standard conditions
$\mathrm{ECP}(\Sigma)_{\mathrm{r\|s}}^{\mathrm{a}}$	Modeled reporting period primary energy consumption adjusted to standard conditions
$\mathrm{ECP}(\Sigma)_{\mathrm{i}}$	Intermediate period total primary energy consumption
$\mathrm{ECP}(\Sigma)_{\mathrm{b\|i}}^{\mathrm{a}}$	Modeled baseline period primary energy consumption adjusted to intermediate period conditions
$\mathrm{ECP}(\Sigma)_{\mathrm{i\|r}}^{\mathrm{a}}$	Modeled intermediate period primary energy consumption adjusted to reporting period conditions
$\mathrm{ESD}(*)$	Delivered energy savings of an unspecified energy type
$\mathrm{ESP}(*)$	Primary energy savings of an unspecified energy type
$\mathrm{m}(*)$	Primary energy conversion multiplier for the unspecified type of energy
$\mathrm{ecm}(*)$	Energy conversion multiplier for the unspecified type of energy
$\mathrm{egm}(*)$	Electricity generation multiplier for the unspecified type of energy

Annex B - Normative: Energy Multipliers

This annex provides unit conversion factors to convert from commonly available units to energy units in BTUs. If an alternative common energy unit is used, the user must document and apply correct unit conversion factors for the alternative unit.

This annex provides defaults value for calculating primary energy from delivered energy. Primary energy consumption (in BTU) is calculated by multiplying the delivered energy (in BTU) by a primary energy conversion multiplier ($\mathrm{m}(*)$), which is the sum of the energy conversion multiplier ($\mathrm{ecm}(*)$) and electricity generation multiplier ($\mathrm{egm}(*)$).

TABLE 4 - CONVERSION FACTORS FOR DELIVERED ENERGY [4]

Energy Type	Measurement Units	Unit Conversion Factor		Energy Conversion Multiplier	Electricity Generation Multiplier
Steam: fired[5] boiler	pounds	Per steam tables[6]	BTU/lb	1.33	1.0
Steam: electric[7] boiler	pounds	Per steam tables[6]	BTU/lb	1.0	3.0
Hot water: fired[5] boiler	gallons x °F	8.34	BTU/(gal °F)	1.33	1.0
Hot water: electric[7] boiler	gallons x °F	8.34	BTU/(gal °F)	1.0	3.0

[4] These values calculated using mechanical engineering references such as Marks' Standard Handbook for Mechanical Engineers, 10th Edition. Eugene Avallone and Theodore Baumeister III.McGraw Hill. 1996.
[5] Multiplier calculated using 1/combustion efficiency, assuming efficiency of 75%
[6] Must know steam temperature and pressure. Values taken from steam tables should subtract out the enthalpy (BTU/lb) of water at inlet conditions. Also, need to know the steam quality if operating in a two-phase region. Steam tables used, whether online or in books, should be based on the International Association for the Properties of Water and Steam (IAPWS). The details of this formulation are found in "Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use" by W. Wagner and A. Pruss, 7 June 2002. (http://www.nist.gov/data/PDFfiles/jpcrd617.pdf)
[7] 3.0 is the default factor for primary energy to grid-delivered electrical energy. The facility should use the same factor for converting electricity from the grid throughout their calculations. Any factor other than 3.0 must be approved by the SEP™ Administrator.

Energy Type	Measurement Units	Unit Conversion Factor		Energy Conversion Multiplier	Electricity Generation Multiplier
Chilled water[8]: fired[5], absorption chiller	ton-hours	12,000	BTU/ton-hour	1.25	1.0
Chilled water[8]: fuel, engine driven compressor	ton-hours	12,000	BTU/ton-hour	0.83	1.0
Chilled water[8]: electric[7]	gallons x °F	8.34	BTU/(gal °F)	0.24	3.0
Compressed air[9]	cubic feet (ft^3)	10.93	BTU/ft^3	1.0	3.0
Grid-based electricity	kWh	3,412	BTU/kWh	1.0	3.0
Solar-based electricity	kWh	3,412	BTU/kWh	1.0	1.0
Wind-based electricity	kWh	3,412	BTU/kWh	1.0	1.0
Geothermal based electricity	kWh	3,412	BTU/kWh	1.0	1.0
Solar or geothermal hot water or steam	BTU	1		1.0	1.0
Agricultural residues[10]	pounds	6,800 - 10,000	BTU/lb	1.0	1.0
Herbaceous crops[10]	pounds	7,791	BTU/lb	1.0	1.0
Woody crops[10]	pounds	8,852	BTU/lb	1.0	1.0

[8] Multiplier calculated using 1/COP. COP = coefficient of performance. It measures the relationship between the heat supplied or removed from a system and the work output from the system.

[9] Compressed air default value assumes a motor driven compressor at 100 psi only. The value of compressed air as an energy source under other conditions can be calculated using site-specific conditions of delivered pressure, the efficiency of the compression equipment for the compression ratio needed at the delivered pressure, the altitude, the efficiency of the part load control mechanisms and controls, and the efficiency of the motor(s), engines, or turbines driving the compression equipment.

[10] Biomass Unit Conversion factors (Higher Heating Values) should be taken from the Oak Ridge National Laboratory *Biomass Energy Data Book – Appendix A*. This reference also outlines a methodology for accounting for material moisture content.

Energy Type	Measurement Units	Unit Conversion Factor		Energy Conversion Multiplier	Electricity Generation Multiplier
Forest residues[10]	pounds	7,082	BTU/lb	1.0	1.0
Urban residues[10]	pounds	5,600 - 11,800	BTU/lb	1.0	1.0
Other biogas / biomass / biofuel[10]	Varies	See Appendix A of ORNL *Biomass Data Book*	Convert to BTU	1.0	1.0
Still gas[10]	ft^3	1,584	BTU/ft^3	1.0	1.0
Digester gas[10]	ft^3	619	BTU/ft^3	1.0	1.0
Natural gas[10]	therms	100,000	BTU/therm	1.0	1.0
Hydrogen gas[10]	ft^3	343	BTU/ft^3	1.0	1.0
Liquid hydrogen[10]	pounds	60,964	BTU/lb	1.0	1.0
Coal[10]	See invoice	See invoice for higher heating value	Convert to BTU	1.0	1.0
Petroleum coke[10]	pounds	13,460	BTU/lb	1.0	1.0
Propane[10]	pounds	21,597	BTU/lb	1.0	1.0
Crude oil[10]	gallons	138,350	BTU/gal	1.0	1.0
Conventional gasoline[10]	gallons	124,340	BTU/gal	1.0	1.0
Low-sulfur gasoline[10]	gallons	121,848	BTU/gal	1.0	1.0
U.S. conventional diesel[10]	gallons	137,380	BTU/gal	1.0	1.0
Low-sulfur diesel[10]	gallons	138,490	BTU/gal	1.0	1.0

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